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DEVELOPMENT OF TRAVELLING WAVE ACCELERATING STRUCTURE FOR A 10 MeV E-LINAC

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Abstract

Electron irradiation processing is a vital application field of nuclear technology application. China Institute of Atomic Energy (CIAE) developed several 10 MeV high power electron irradiating accelerators successfully, promoting the development of high energy high power irradiating accelerator technology and electron irradiation processing in China. The paper introduced the development of a 10 MeV travelling wave accelerating tube. The tube operates at 2856 MHz in $2\pi/3$ mode. The SUPERFISH and PARMELA are used for the physical design. Several methods are used for microwave parameter measurement and tuning. The high power test shows the beam energy is 10.3 MeV and average beam power is 24.3 kW.

INTRODUCTION

The R&D of accelerating tube consists of physical design, mechanical design, tuning and high power test. Based on these steps, a 2-meter long 10 MeV travelling wave accelerating tube is developed. The tube consists of 58 cells, including 6 nonuniform cells (bunching section) and 52 uniform cells (accelerating section). The parameters for the accelerating tube are collected in the Table 1.

Table 1: 10MeV Travelling Wave Accelerating Tube Parameters

Parameter	Value
Beam energy	10MeV
Average beam current	>2mA
Input pulse power	5MW
Duty factor	0.9%
Phase velocity in the first cell	0.4
Bunching section length	15.6cm
Total length	1.971m

In the following sections, the key points in each R&D step of the 10MeV accelerating tube are described.

PHYSICAL DESIGN

The electric field intensity and phase velocity increase linearly in the bunching section. The accelearating section uses constant impedance structure, which meams 52 uniform cells are totally the same.

SUPERFISH and PARMELA are used to calculate the electromagnetic field and dynamics.

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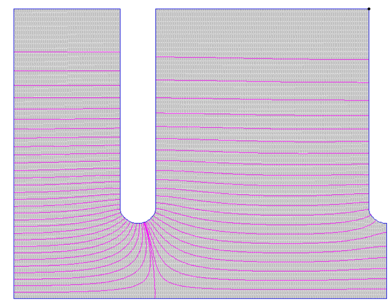

Figure 1: $2\pi/3$ mode electromagnetic pattern with SUPERFISH.

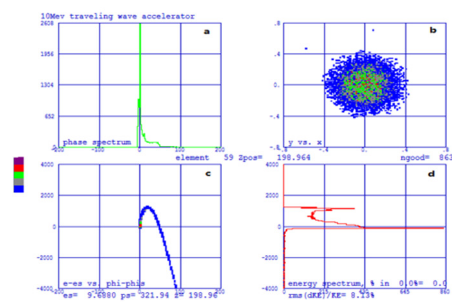

Figure 2: Simulation with PARMELA.

As we can see in Fig. 2, most electrons within a microwave period are bunched into a relative narrow width of phase. Beam spot is about 8 mm and energy spread is less than 10% at output of the tube, which meet the requirement of electron beam radiation processing.

MECHANICAL DESIGN

Mechanical Design

Accelerating cells use cup-type (or called bowl-type) structure. Compared with disk-ring structure, the cup-type has better stiffness, as well as less brazing seam.

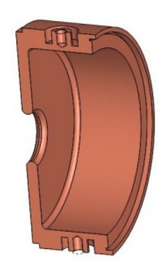

Figure 3: Cross-section of cup-type cell.

In the wall of each cell, two tuning holes are machined with 12mm diameter and 1mm thickness. Meantime a smaller tuning hole is machined in each tuning hole so that the cell can be pressed or pulled to increase or decrease the resonance frequency of the cell respectively when tuning after brazing.

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TUNING

The tuning procedure consist of three parts: cell tuning, coupler matching and tuning after brazing.

Cell Tuning

Probe method [1] is used for cell tuning, as showed in Fig. 4. The plunger with the probe inside is in the center of the cell. Then we can get the π/2 mode frequency of the cell right between two plungers, $f_{\pi/2,a}$. On the other side, we can use SUPERFISH to calculate the π/2 mode frequency of the cell, $f_{\pi/2,b}$. If $f_{\pi/2,a} = f_{\pi/2,b}$, the cell is tuned properly.

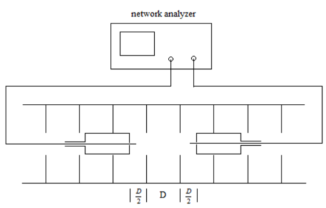


Figure 4: Probe method.

Coupler Matching

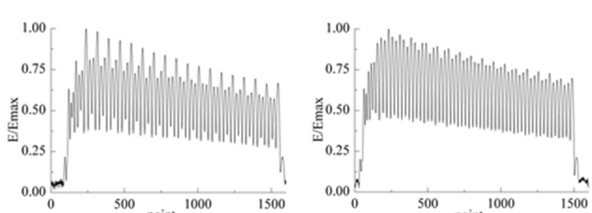
We use Kyhl method [2] and its improved method to match coupler. In short, we need get the phase value of three frequencies when detuned coupler cell and its neighbour cell respectively. The three frequencies are frequency for π/2 mode, $f_{\pi/2}$, frequency for 2π/3 mode, f2π/3, and mean value of $f_{\pi/2}$ and $f_{2\pi/3}$, f_{mean}. If the phase changes in the matching procedure satisfy a certain relation, the coupler is properly coupled and tuned. The result of output coupler matching is showed in Table 2.

Table 2: Result of Output Coupler Matching

	Phase of $f_{\pi/2}$	Phase of f_{mean}	Phase of $f_{2\pi/3}$
Detuned coupler	118.3	113.6°	108.8°
Detuned neighbour cell	-1.4°	-66.7°	-131.9°
Phase changes	-119.7°	-180.3°	-240.7°

Tuning After Brazing

Bead-pull method [3,4] is used to get travelling wave field distribution along the axis direction. The analyse model is built to get frequency difference of each cell. We can use the tuning holes to tune cell by cell. The Fig. 5 shows the field distribution before and after tuning.



Before After

Figure 5: Travelling waves field distribution before&after tuning

Compared with travelling waves field distribution before tuning, the final field distribution becomes much better. The amplitudes of the scattered waves are minimized. At this time, the curve of VSWR vs. frequency is showed as Fig. 6. The VSWR is 1.03 at 2856Mhz and bandwidth is about 4MHz (VSWR ＜1.2)

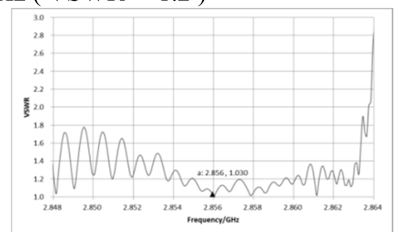


Figure 6: The measurement result of VSWR vs. frequency.

HIGH POWER TEST

The high power test stand consists of 100kW modulator, 5MW/45kW klystron, cooling machine, microwave system and control system. High power test is tested by National Institute of Metrology (NIM), China. The energy of the electron beam is 10.3 MeV as showed in Fig. 7. The average beam power is 24.3 kW in condition of 480 Hz pulse repetition frequency and 16 μs pulse width.

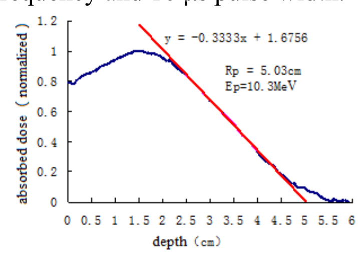


Figure 7: Result of energy test.

CONCLUSION

The R&D procedure of a 10 MeV travelling wave accelerating tube involves several key techniques. The application of these techniques and the establishment of test benchs give support to industrial application and further optimization of 10 MeV travelling wave accelerating tube in China.

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